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UNIVERSALHOMESERVICEGATEWAY - A HARD- AND SOFTWARE PLATFORM AS A CORE COMPONENT FOR SMART GRIDS

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ABSTRACT

The „UniversalHomeServiceGateway“ (UHSG) provides a central platform in order to realize a „Smart Home“. It also enables “Application Service Provider” to provide various software components to a customer, i. e. Smart Metering. By implementing standardized as well as proprietary interfaces the UHSG can easily be integrated into existing solutions such as the herein presented Smart Metering project which exists in cooperation between HTWG Konstanz and Stadtwerke Konstanz GmbH.
Containing a powerful ARM9 micro controller running a standard Linux operating system with Java capabilities, it also supports various hardware interfaces. This allows the use of more complex technologies and frameworks – such as the OSGi framework.
The OSGi framework is a Java based framework which allows installing, starting, stopping, updating or removing components, the so called bundles, at runtime. It is possible to manage the software components on an UHSG remotely via a central management system – software components can be installed, updated or removed.
The project's hardware supports the RS485 bus running a proprietary Smart Metering protocol as well as the standardized IEC62056-21 “1107” protocol. The UHSG also consists of additional interfaces like wireless MBUS, XBEE and Ethernet. Furthermore a S0 impulse interface is provided which is used by many electric meters that are currently in the field.

Index Terms **–** UniversalHomeServiceGateway, OSGi, Java, Smart Metering, Smart Grid

1 INTRODUCTION

Reducing CO_2 emissions and achieving a sustainable energy network are key questions of our time. The costs of non-realized energy saving potentials in the European Union are estimated to about 100 Billion Euro each year. [1].

Milestones on a European level are the EU-directive about energy end-use efficiency and energy services [2] (EDL-directive) from April 2006 as well as the “20/20/20-Energiezielvorhaben” (guidelines for year 2020: 20% CO2 reduction, 20% renewable energy, 20% energy savings) of the European Union [3].

Those aims can only be achieved by energy saving mechanisms, a rise in energy usage efficiency and consequent exploitation of renewable energy sources. Therefore several future technological improvements are necessary as well as raising the energy usage awareness towards responsible use of the available energy resources.

The information- and communications technology (ICT), which is the base of an intelligent network of all components of energy systems, is a key component in the development of future energy networks.

2 ENERGY SUPPLY IN GERMANY

The topology of classic energy networks will be changed in a fundamental way through small, decentralized energy generators. The traditional process of a centralized energy generation, transportation and distribution will become fully or even partly obsolete [4].

In the medium term the currently well developed distribution networks will reach their limits due to constantly growing energy needs. Load smoothing by distributing high energy peaks in an intelligent way can help to avoid a lot of costly investments that otherwise would be necessary only for a few peek hours of the day.

Distribution network provider have to transform from pure energy distributors to proactive controlled energy network operators. The complex operation of such a network is only possible through fully organized, automated and intelligent energy networks, the so called „Smart Grids“.

The basic component of such intelligent networks is automated meter reading, called „Smart Metering“. Smart Metering enables energy providers the possibility to read the consumption of their customers automatically and nearly in real time. It is possible to perform all controlling operations and maintenance functions through a central point.

However, the key to success is a standardized communication platform based on Internet technologies.

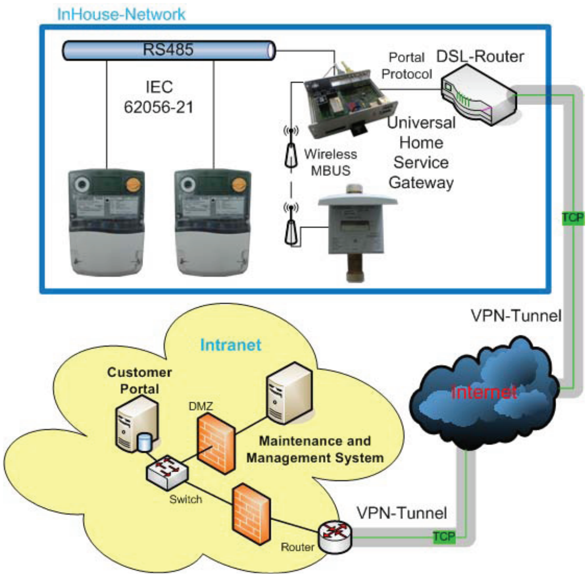

Figure 1: Smart Metering System Overview

3 SMART METERING AND SMART GRID

Smart Metering is part of a hierarchical system called the „Internet of energy". It is essential for the energy supply of future generations. The main part in every Smart Metering infrastructure is the communications access to meters and therefore houses of customers. Figure 1 shows our Smart Metering system architecture.

3.1 Smart Metering – The automatic meter reading

Metering was faced to many changes in past. The subject of automated remote meter reading can be divided into two concepts, the "AMR"- as well as the "AMI"- respectively "AMM"-systems.

Characteristic for AMR-systems (Advanced Meter Reading) is an unidirectional communication from meters towards the reading devices [5].

AMI- (Automatic Metering Infrastructure) respectively AMM-systems (Automatic Metering Management) can be characterized by a bidirectional communication. Meter reading as well as tariff- and control-information can be exchanged with those meters. They commonly are called „intelligent meters".

Future requirements can't be met with unidirectional AMR solutions, only AMM solutions are able to serve them.

3.2 From Smart Metering to Smart Grid

The term „Smart Grid" combines holistic organized, automatic power grids of the future which support remote control, load distribution and storage and generation of energy.

The interconnection of energy sources at a local and regional level by central servers leads to a more reliable forecast of energy needs. Inefficient generation and consumption peaks could so be eliminated.

A system wide usage of ICT across all levels of energy networks, from the generator to the consumer, is an essential need for the functionality of Smart Grids.

4 CURRENT AND FUTURE CUSTOMER BEHAVIOR

The customer view to Smart Metering as well as the general acceptance will change in medium term. This can be attributed to a change in individual customer behavior.

Today people tend to see it as granted that energy is everywhere and available every time in sufficient quantity. This kind of view is questioned by current development.

The future customer will frequently analyze his consumption and will try to optimize it. Therefore he has to become aware that energy is a valuable good. Here Smart Metering systems can help by visualizing all relevant data.

4.1 Change in consumer behavior

The majority of energy consumption and the resulting costs are related to consumer behavior.

Several aspects have to be taken into account [6] because bare visualization of energy consumption doesn't automatically change a consumers behavior:

- Is there concrete information on how to save energy?
- Possibility of the Comparison with a „standard consumer"
- Presentation of concrete advantages resulting from energy savings
- Feedback on achieved savings
- Consumption- and cost-visualization

The savings expected from long-term change in behavior are higher and more sustainable then the ones resulting from short-term and one-time effects.

5 FEEDBACK SYSTEM REQUIREMENTS

Feedback systems exist in order to visualize energy consumption. They represent the concrete interface between the Smart Metering system and the consumer.

Feedback systems can be realized by many different technologies with a lot of different functionalities and in nearly every price category.

Several studies were made, concerning the use and the practicability of such feedback systems. All of them share the common result that the quality of a

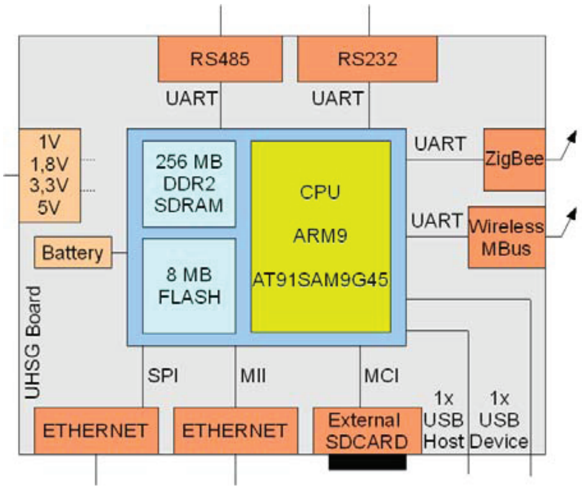

Figure 2: UniversalHomeServiceGateway

feedback system is defined by its user's acceptance. However this acceptance highly depends on the individual visualization, easy to apply energy saving recommendations and the possible energy savings that may result from using the feedback system.

Indirect feedback systems present structured offline data such as the visualization of the impact of building measures. The energy saving potential of such indirect feedback systems are up to ten percent depending on quality and context of the used data. Those energy savings are much more sustainable then one-time effects achieved by direct feedback systems, which directly present the actual energy consumption. Therefore indirect feedback systems, mainly realized as customer portals, have a much higher energy saving potential and can offer a variety of additional benefits.

However the visualization should focus on a clear and continuous structure. The main benefit of such systems is the option to realize additional value. This can be a simple visualization of the current load (in Watts or kW), as well as extensive statistics or higher level functionalities like control operations.

6 UNIVERSAL HOME SERVICE GATEWAY

The UHSG is based on an ARM9 micro controller [7] with 256 MByte DDR2 SDRAM. It includes a number of different hardware interfaces to communicate with several external devices. For communication with Smart Meters it has a RS485-Interfaces, MBUS wireless interface and a XBee interface. The RS485 bus can be used to connect to Smart Meters supporting the IEC EN 62056-21 protocol or proprietary protocols like the one used in combination with our own S0-Gateways.

Two Ethernet interfaces are able to connect the UHSG to external networks. So a data collector can retrieve prior collected metering values via TCP/IP. For maintenance, a web interface with an integrated

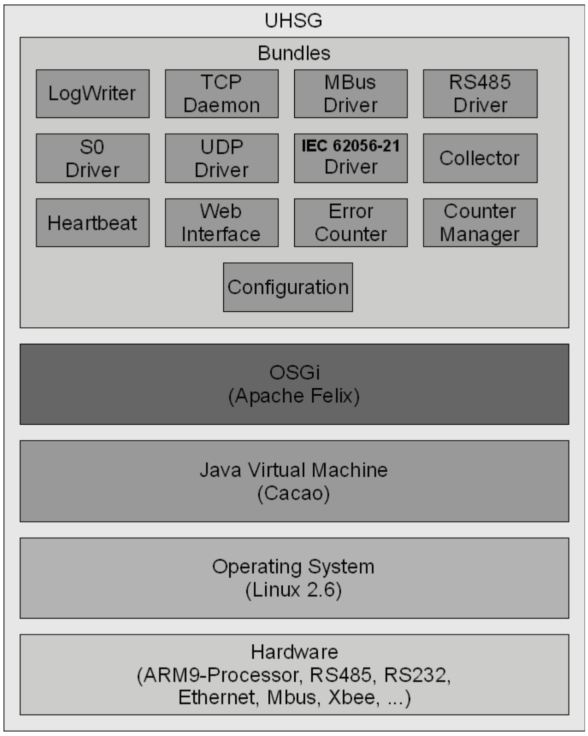

Figure 3: UHSG Software Architecture

web server allows direct access to several functions of the UHSG.

Configurations can be stored as well as metering values as well as further important data. They are stored in the file system on SD-card.

Additionally the UHSG contains two host USB interfaces and one device USG interface.

Figure 2 shows the UHSG with all interfaces.

The powerful micro controller enables the UHSG to run an embedded Linux operating system with its features like a Java Runtime Environment and a Java framework called OSGi (Open Service Gateway Initiative) [8].

The OSGi framework provides a dynamic and hardware independent software platform. Software components created for the OSGi framework are called “bundles”. Bundles can easily be deployed, undeployed or updated at runtime. The pure OSGi framework is just a collection of interfaces. Currently several implementations are common available. OSGi bundles can be deployed to any implementation of the OSGi specification. Here the implementation of Apache Software Foundation – “Apache Felix” [9] – is used.

Given this architecture we implemented several bundles to integrate the UHSG in our Smart Metering system. There are bundles for heartbeat, web interface for management tasks, error reporting. There is also a collector bundle for reading different meters. It has a driver architecture which separates the meter reading logic from the actual device access. Several device drivers can be registered to that collector bundle, i. e.

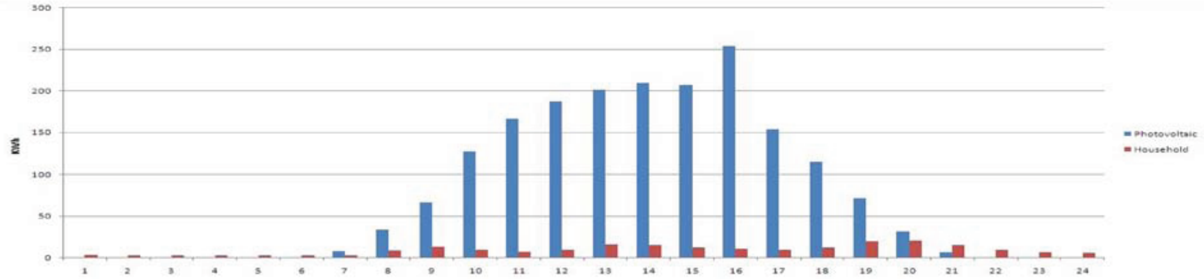

Figure 4: Photovoltaic and household comparison

RS485 driver, IEC 62056-21 driver, Wireless MBus driver, XBee driver, etc. Figure 3 illustrates the software architecture of the UHSG.

With the OSGi framework, an Application Service Provider (ASP) can easily provide software bundles to its customers. With a management interface, realized as a web interface the ASP is able to provide only those bundles to its customers to which they have subscribed to. Furthermore the ASP can update, install or remove existing software bundles remotely.

Based on such powerful hardware-software-combination a large number of services and interfaces can be implemented. This includes Smart Metering protocols, proprietary protocols, Smart Home software, user interfaces like web pages or touch screens, etc. Currently we are implementing the support of the IEC EN 62056-21 protocol that is used by many Smart Meters as well as the Smart Metering Language (SML) in order to better integrate with higher level management systems.

7 MAINTENANCE AND MANAGEMENT SYSTEM

The central instance for maintenance and management of the Smart Metering system is based on the open source application and portal server JBoss [10] [11]. Because all web modules are compatible to JSR 168 specification [12], it is possible to integrate them into other portal servers. Additionally, by using JSR 168 compatible portlets high application flexibility and fast development cycles can be achieved.

We set up an Advanced Metering Infrastructure (AMI) which can be fully configured via the maintenance- and management-portal. The configuration allows, amongst other features, load balancing and data aggregation.

Due to the fact that metering points can use DSL as communication link to the Internet, the problem of periodically changing IPv4 addresses has to be solved. Our approach faces this problem by receiving so called ‘heartbeats’ from DSL metering points. For time synchronization we are using an internal time server which synchronizes it's time via DCF77. The complete behavior of collecting, aggregating and forwarding of metering data, receiving ‘heartbeats’ and propagating system time can be configured via corresponding configuration modules which were also developed and integrated into the system.

Due to our vision, remote meter reading is only one possible application. As a consequence the software design allows reuse of services, e. g. open secure connections to a metering point. This flexibility enables the system to provide metering points with additional services or software updates. For this purpose a remote OSGi management Web module was developed, which allows the remote installation, check or removal of OSGi bundles on the UHSG metering point. One example for this application bundle could be a smart home application similar to the one described by M. Jahn et al. [13].

To keep track of the system status, all actions, unwanted behavior or errors are logged in a centralized database. Furthermore fatal errors are forwarded to external systems like E-Mail or master display. To simplify the process of taking a new UHSG into service, the metering point configuration can be edited in the management system and downloaded by the UHSG when it first connects to the management system.

Future work has to be spent on the smooth integration of new services in the base system, with the aim to enable customers to book new services via the customer portal and provide suitable ‘easy-to-use’ frontends.

8 CUSTOMER PORTAL

To our view, the most essential part of a metering feedback system is ease of use, availability, extensibility and data accuracy. To achieve these aims, we decided to implement a customer portal which is also part, although not in the physical sense, of the maintenance and management portal. The management services are responsible for the configuration and preprocessing of the metering data while the customer portal modules only display the processed data.

Figure 4 shows a customer chart. The chart shows the average energy consumption in kWh per hour of a randomly picked pilot household in June 2010 and the

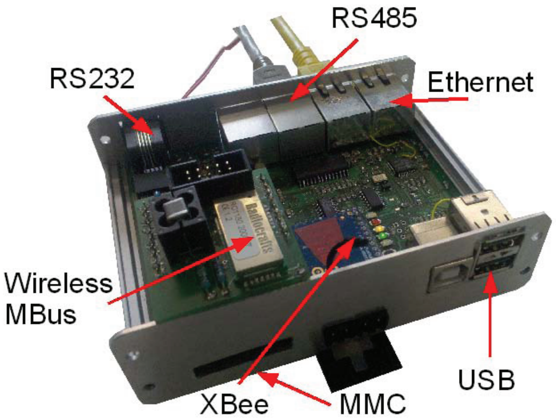

Figure 5: UniversalHomeServiceGateway Prototype [14]

average energy generation in kWh per hour of a pilot photovoltaic plant. The production during midday is in average 10 times higher than the average household consumption. The numbers illustrate, that if the customer does energy intensive actions during midday, or produced energy could be stored for the less daylight intense hours, the energy of the sun could by far be better used and CO_2 emission could be reduced. Smart Home applications enable the customer to make informed decisions on his energy consumption. Additionally applications can shift energy intensive activities automatically to a definite time point. Such applications could be the first step towards a Smart Grid.

The customer portal in the current version supports the display of daily, weekly, monthly, yearly load profiles and cost overviews. Access to historic data is also available and can be used to create consumption forecasts, or tariff proposals. Additionally customers can download detailed cost overview documents.

In the future, the customer will be able to choose which data will be provided and stored for online access.

9 CONCLUSION

The UniversalHomeServiceGateway is a first step to the Smart Grid. It enables energy provider to automatically manage the grid and connected consumer devices. New devices like washing machines, computers, TVs, etc. can easily be integrated and controlled by the UHSG by installing new OSGi bundles.

We are running a pilot installation with three apartment blocks containing several HomeServiceGateways [15]. The pilot installation is integrated in our Smart Metering system. Figure 5 shows a prototype of the UniversalHomeServiceGateway.

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